

## ME 4811

### Lab #4: Tracking Systems/Feedforward Control

Consider the “Phoenix” equations of motion as developed in the previous labs. If a lateral underwater current with absolute velocity  $v_0$  is present, the last equation needs to be modified as in

$$\dot{y} = \sin \psi + v \cos \psi + v_0$$

where the rest of variables and equations are the same as before.

#### **Do the following:**

1. Simulate the system using the control law that you developed in Lab #2. Use two values for the current,  $v_0=0.1$  (i.e., a current equal to one tenth of the ship speed) and  $v_0=0.5$  (half the forward speed of the ship). How is your control law performing? Is there a steady state error in  $y$ ?
2. Evaluate the above steady state error in  $y$  analytically from the state equations and check your simulation results. Make a plot of the steady state error versus  $v_0$ . Make sure that you properly account for the possibility of saturation for the rudder angle  $\delta$  in your calculations.
3. In order to get rid of the steady state error introduce a feedforward term in the control law; i.e.,  $\delta = -(k_1\psi + k_2v + k_3r + k_4y + k_0)$ . Find the value of  $k_0$  to ensure zero steady state error in  $y$ . Simulate the system and plot both  $(y,t)$  and  $(\psi,t)$ . Use both current values. Now  $y$  should be zero at steady state. Is the heading angle also zero? If not, evaluate the steady state error in the heading angle and check your simulations. This demonstrates the “set and drift” principle; to keep course in a current, the helmsman turns the bow of the ship into the current.
4. Look at the picture of the vehicle in Lab #1. Can you suggest how we might achieve both  $y$  and  $\psi$  to be zero in the presence of a current?